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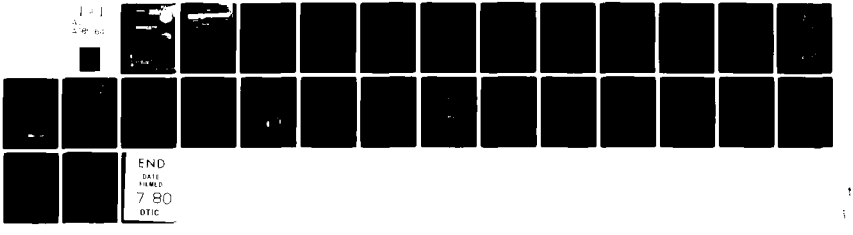

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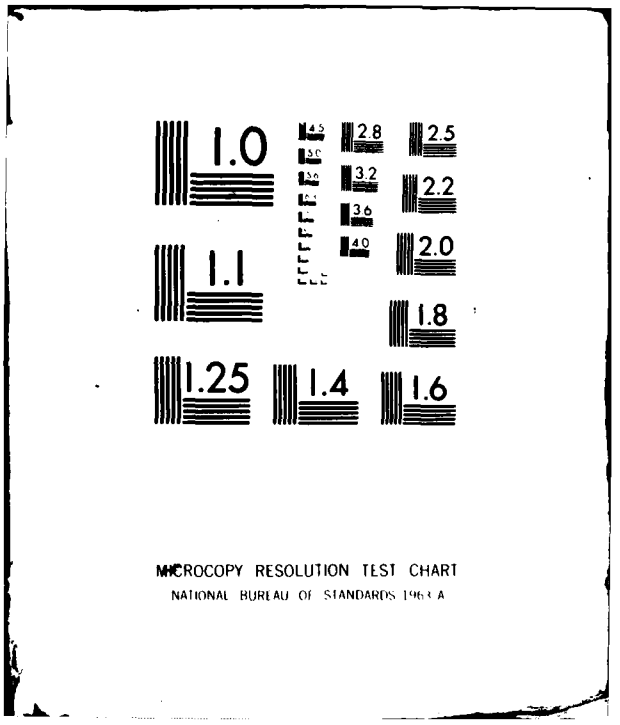
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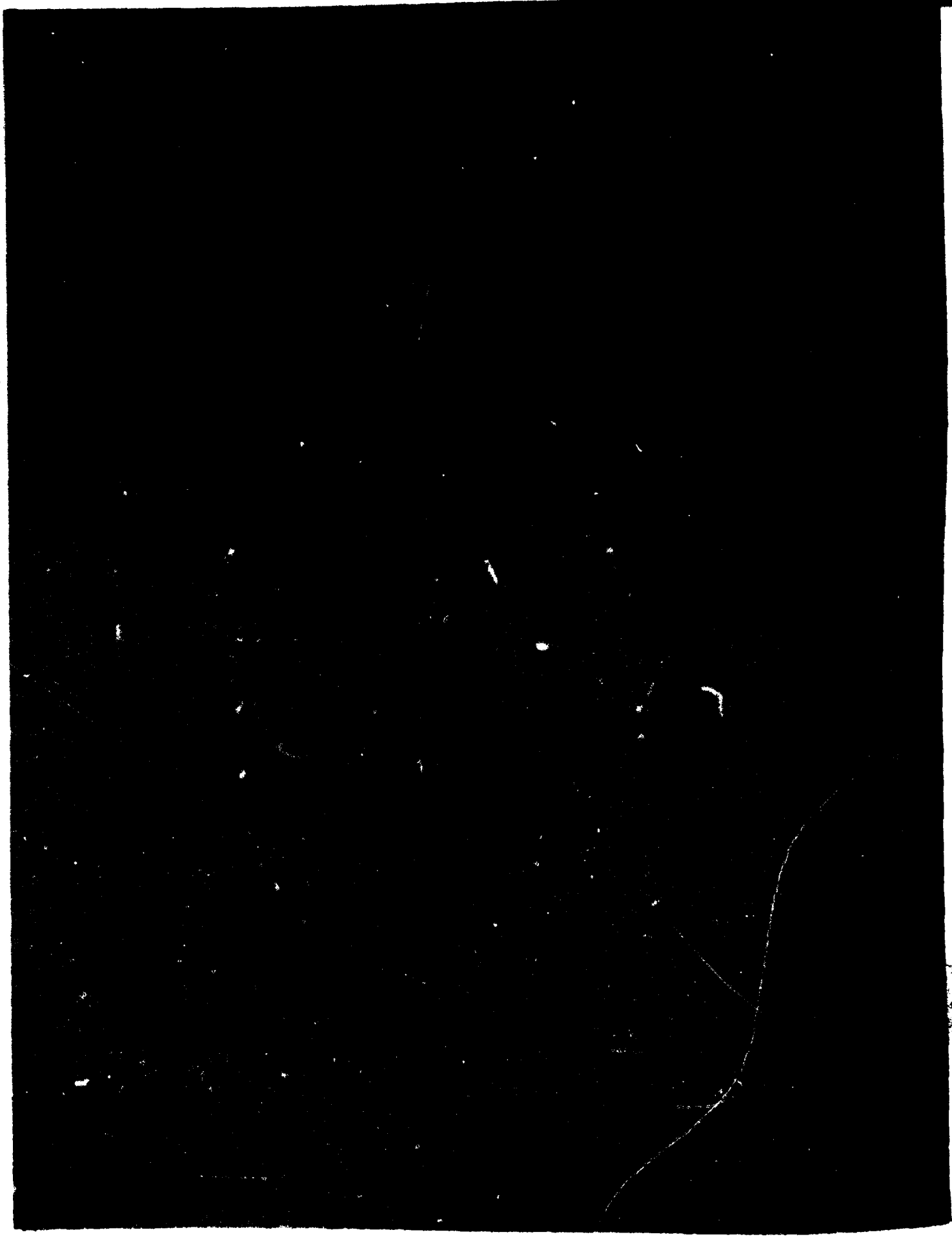

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Linear Acceleration	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this report is to provide a general description and the capabilities of several unique vibration facilities located at the Biodynamic Effects Branch of the Biodynamics and Bioengineering Division of the Air Force Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base, Ohio 45433. All of these devices are currently maintained under Government contract by the University of Dayton Research Institute.

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Block 20. (Continued)

This report specifically deals with the following devices:

(1) SIXMODE Motion Simulator,
(2) Vertical Accelerator,
(3) Combined Noise and Vibration Facility,
(4) C-5 Electrodynamic Vibration System.

Reference should be made to the bibliography at the end of this report for technical reports dealing with specific capabilities and examples of experiments conducted on these devices.

PREFACE

This facilities summary report was done under Air Force Contract No. F33615-79-C-0509 with the Air Force Aerospace Medical Research Laboratory (AFAMRL). SMSgt. Jerry Beinlich of AFAMRL/BBD was the Project Monitor.

Other personnel who made contributions to this report were George T. Collins of the University of Dayton, and Dr. Richard Shoenberger and Robert Ewing of AFAMRL/BBD.

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SECTION 1
INTRODUCTION

The purpose of this report is to provide a general description and the capabilities of several unique vibration facilities located at the Biodynamic Effects Branch of the Biodynamics and Bioengineering Division of the Air Force Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base, Ohio 45433. All of these devices are currently maintained under Government contract by the University of Dayton Research Institute.

This report specifically deals with the following devices:

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SECTION 2

GENERAL DESCRIPTIONS AND SPECIFICATIONS OF FACILITIES

SIXMODE MOTION SIMULATOR

The SIXMODE motion simulator and its associated hydraulic power supply is a large complex man-rated electrohydraulic machine capable of sinusoidal, quasi-random, or random motion in six-degrees of freedom. There are six large servo controlled hydraulic actuators which drive the system. Motion can be controlled in all combinations of x, y, z, roll, pitch, or yaw.

The SIXMODE control system includes a complement of sine and random noise signal generators and monitoring equipment, including a seven-channel sine generator for quasi-random (sum of sines) programs. Experimental data can be acquired on line using a DEC (Digital Equipment Corporation) PDP-11/34 Data Acquisition and Processing System also data can be stored on high density disks for later analysis. Forcing functions can also be generated by the PDP-11/34 System. The forcing functions for the SIXMODE are controlled by a multiaxis programmer. This device provides for selecting individual operating modes or combinations of modes. Each selected mode has its own individual forcing function input, as well as variable gain control.

An automatic shutdown system (ASDS) monitors both linear and angular accelerations as well as all six actuator positions. If any of the preset parameters are exceeded the ASDS causes the hydraulic and electronic failsafe systems to be engaged and also commands all electrical driving signals to gradually decrease in magnitude through a "ramp down" function. The hydraulic failsafe and numerous interlocks are also activated if an improper start-up sequence is attempted.

The hydraulic energy to power the SIXMODE is produced by a large hydraulic power supply located in an adjoining area. This power supply is capable of a delivery rate of 1000 GPM at 3000 PSI. The basic system includes 6 axial type hydraulic pumps each driven by a 350 HP electric motor operating at 1800 RPM. More complete specifications for the hydraulic power supply are described in report UDR-TR-79-33.

Each of the six hydraulic actuators associated with the SIXMODE has two 60 GPM servovalves operating in a parallel configuration and six corresponding electronic servo loops which are individually compensated and controlled. The electronic servo loops utilize a hybrid analog computer which affords maximum versatility in changing compensation and actuator responses for specific projects. This hybrid analog computer also allows for pushbutton selection and display of voltages within all six servo control loops. All servovalve power amplifiers and associated power supplies are conservatively rated for maximum subject safety.

The SIXMODE failsafe and interlock systems are equipped with unique failsafe hydraulic manifolds and control solenoids which shunt across both hydraulic control pressure ports for each actuator, in the event of a malfunction. The key to this failsafe system is a movable hydraulic spool held in place by the hydraulic system pressure. Removal of solenoid power or hydraulic pressure causes each hydraulic actuator to lose all driving force and, in essence, the actuators become very "mushy" shock absorbers. Failsafe activation may be accomplished either manually or automatically.

The current man-rating license for the SIXMODE limits operation, with human subjects, far below the maximum capabilities of the system. This policy is concurrent with the practice of setting the ASDS operational limits to only what is needed for an approved human operational protocol. The device can, however, be operated at higher levels with the approval of the Air Force Human Use Committee. Single actuators can also be isolated for

high force, long stroke applications, needed in some non-human or material properties tests.

SIXMODE - General Specifications for Human Protocols

Frequency Range - DC-30 Hz.

Motion - six degrees of freedom, x, y, z, roll, pitch, yaw.

Displacement - system limits are approved for 6 inches double amplitude. (D.A.)

Individual actuators have 10 inches D.A. useable range.

Force - Each actuator is capable of 20,000 force lbs. maximum @ 2,000 PSI.

Acceleration - 1.5 g-peak linear and 15 rad/sec^2 peak angular for human tests. Significantly higher acceleration levels are achievable for non-human tests.

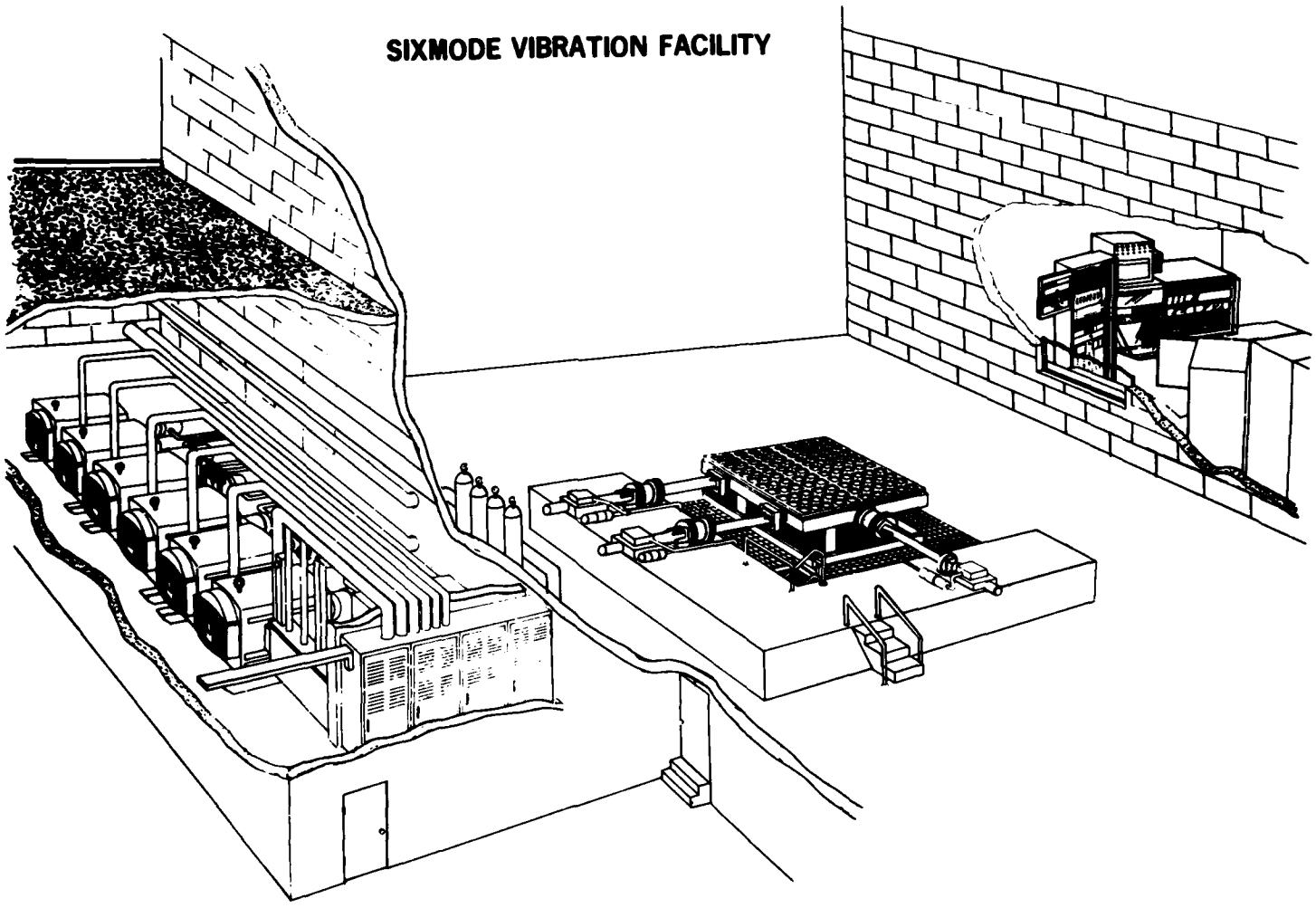
Test Platform - one piece aluminum table 59" x 59" with 5/8 x 18 thread per inch on 5" centers, coupled to six actuators by zero backlash hydrostatic and elastomeric couplers.

Payload - 2,000 lbs. maximum.

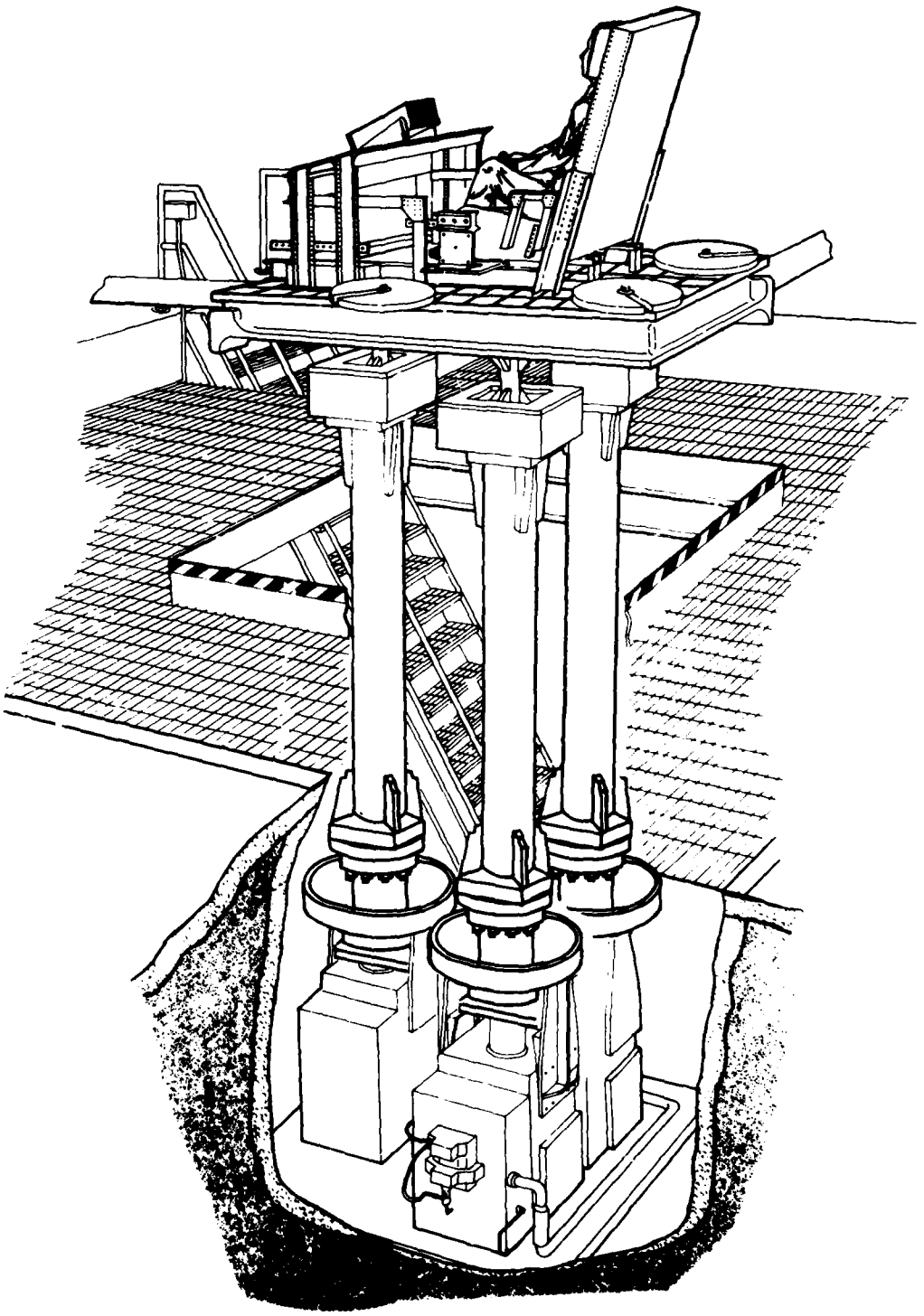
Hydraulic Power Supply - 1,000 GPM @ 3,000 PSI.

Testing limits are set at levels needed to complete existing human test protocols only. Higher limits are achievable for non-human tests.

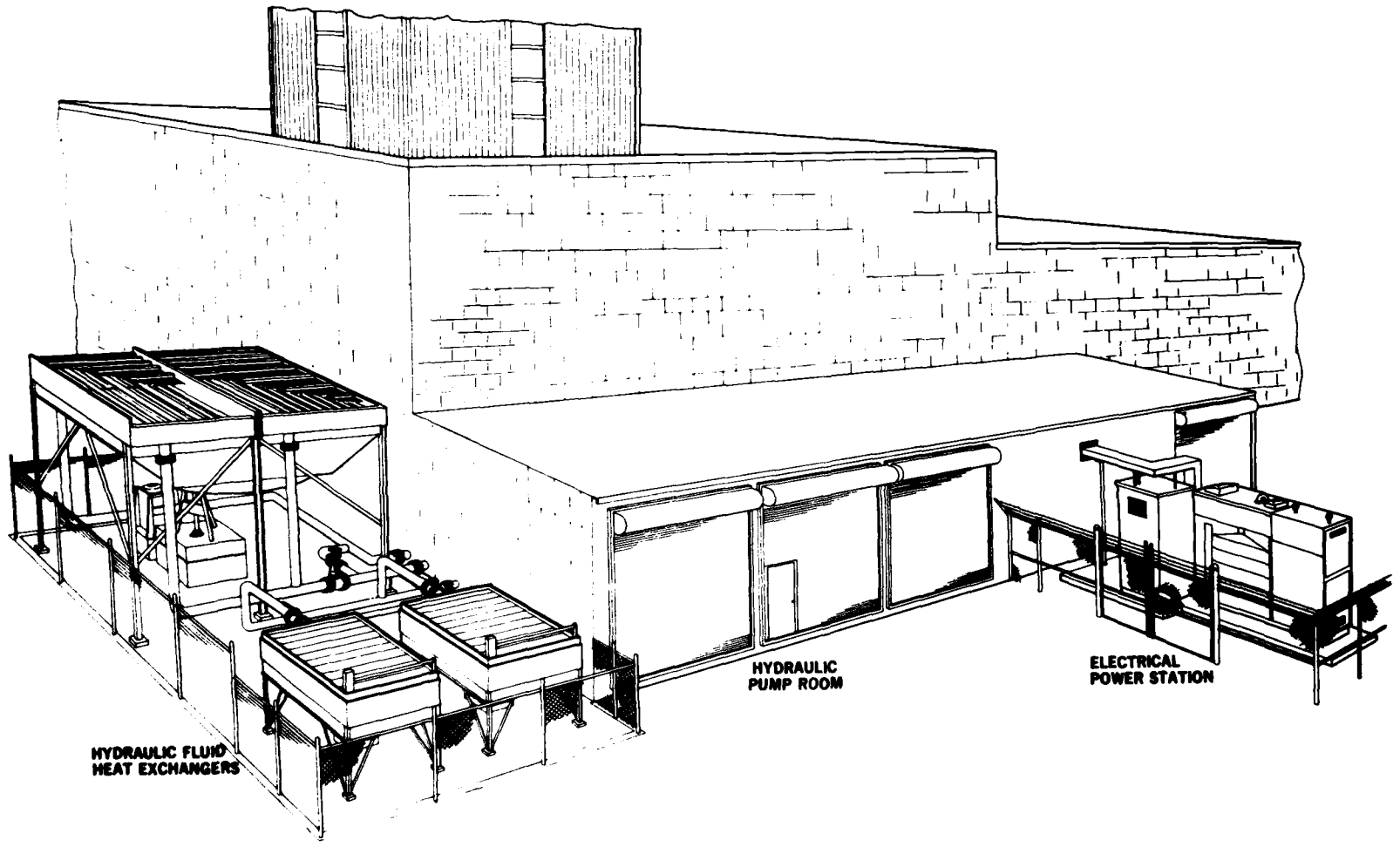
SIXMODE VIBRATION FACILITY



SIXMODE VIBRATION TABLE DETAILS



SIXMODE FACILITY EXTERIOR EQUIPMENT



VERTICAL ACCELERATOR

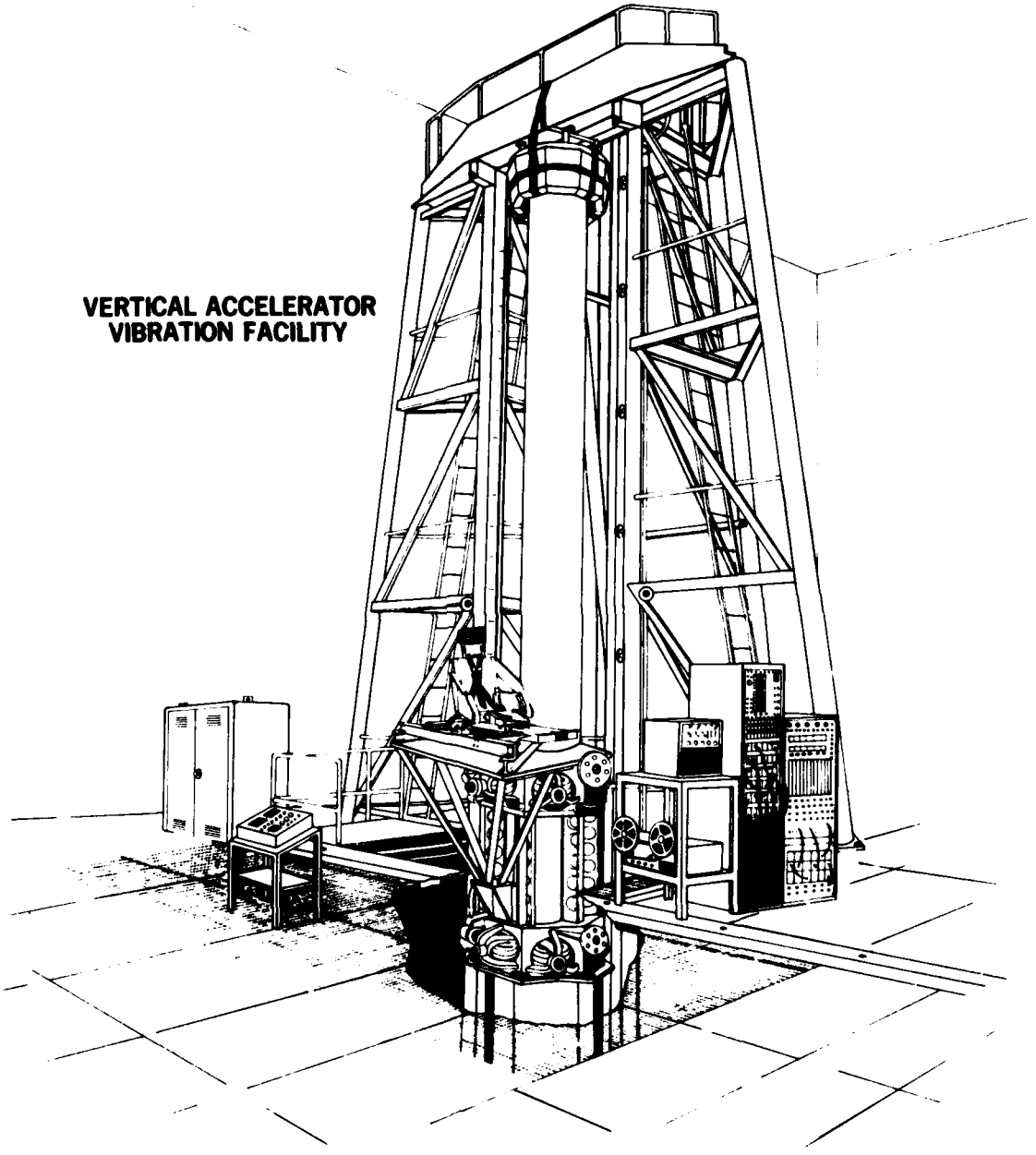
The Vertical Accelerator is a manrated, low-frequency, large amplitude electromechanical simulator with a 10 foot double amplitude capability. This device produces sinusoidal or random acceleration within a 0.2 to 10 Hz frequency range. The Vertical Accelerator was developed to simulate vibration and buffeting encountered in the aerospace environment. The Vertical Accelerator employs a unique friction drive which moves the test platform on a 30 foot ductile iron traction cylinder which rotates at 300 rpm. The supporting framework consists of two steel towers which also incorporate special rails for braking action and support. The test platform or carriage is composed of two hexagonal cast sections encircling the traction cylinder and separated by vertical struts. Each cast section is equipped with six aircraft wheel assemblies that are supported radially by small micarta wheels. Thrust bearings and hydraulic pistons allow traction to be applied for motion and removed for braking action. The braking system is of a fail-safe design. When traction hydraulic pressure is applied the brakes are released to allow motion. With a reduction of hydraulic pressure the brakes are reapplied with spring action. Therefore, any catastrophic loss of hydraulic pressure will result in the brakes being automatically applied on the carriage. The system also incorporates electronic limiters and limit switches to prevent the carriage from traveling beyond the 10 foot range. In addition to the many safety features in the original system, styrofoam shock absorbers were designed and installed to protect the subject if the carriage should inadvertently travel against the upper or lower stops of the machine.

Vertical Accelerator - General Specifications

Frequency	- 0.2 to 10.0 Hz.
Motion	- Sinusoidal or random.
Displacement	- 10 ft D.A. maximum.
Acceleration	- 3 g-peak maximum.
Payload	- 200 lbs. maximum.

NOTE: Maximum displacement and acceleration limits are based on payload, acceptable acceleration distortion, and tire wear.

VERTICAL ACCELERATOR VIBRATION FACILITY



COMBINED NOISE AND VIBRATION FACILITY

The Combined Noise and Vibration facility is a manrated facility consisting of an Unholtz-Dickie Type 250D-56 exciter and lightweight seat and support system. It is enclosed in an environmental test chamber and is controlled from a separate instrumentation and control room. This system was specifically designed for experimental protocols involving the performance testing of human subjects exposed to sinusoidal, or complex uniaxial motion, while being subjected to controlled noise environments. The test chamber is semi-anechoic with temperature and humidity control.

The Unholtz-Dickie Type 250D-56 vibration exciter is an electrodynamic type having a maximum force capability of 1,500 lbs. and operating in the frequency range of DC to 5,000 Hz. The maximum displacement is 1.5 inches D.A. This relative small exciter is made usable for human testing by employing a specially designed platform and chair assembly. This assembly is supported by 4 floor mounted outrigger posts each fitted with special purpose air bags as primary support members. The air bags, which are used instead of springs to offset the structural weight, have a constant force response and allow a good waveform even at the maximum 1.5 inches D.A. excursion. The DC coupled amplifier allows centering of the armature with up to 50 lbs. of payload variation. This feature simplifies human experimental testing where subjects can vary from the 5th to the 95th percentile in weight distribution.

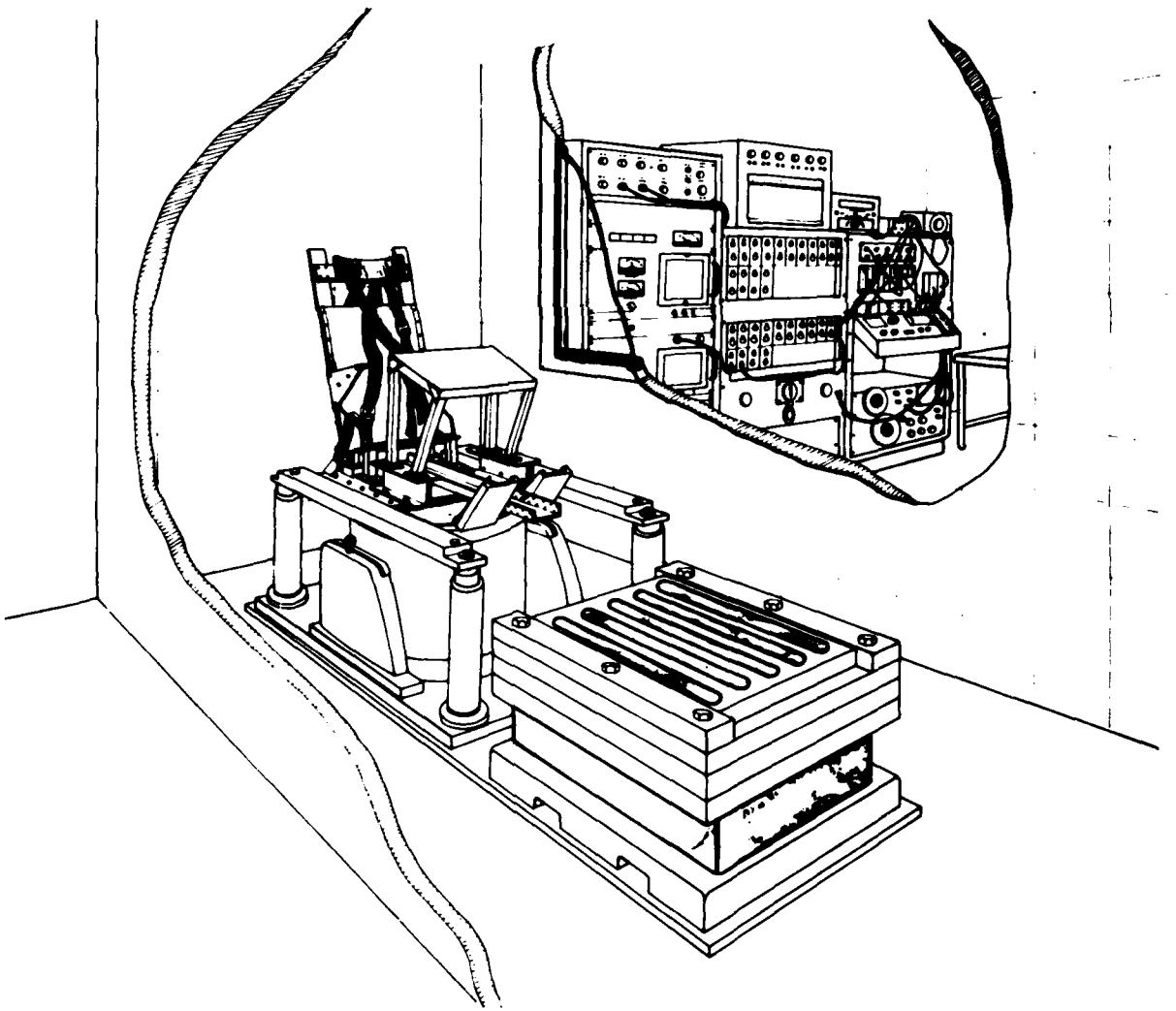
The system is equipped with a specially designed and fabricated automatic shutdown system (ASDS) which ramps the forcing function up to full power during normal operation, and which will also automatically ramp it down to zero power if any of three preset parameter limits are exceeded. The preset ASDS parameters can be selected from a number of functions such as acceleration, velocity, electrocardiogram, etc. System position and thermal limits are also used with the ASDS for maximum safety.

The Combined Noise and Vibration facility can be patched into a DEC PDP-11/34 Data Collection and Analysis System to provide for spectrum analysis, spectrum generation, and/or closed loop control of the shaker system.

Combined Noise and Vibration Facility Specifications

Frequency	- DC to 5,000 Hz.
Motion	- Sinusoidal or random, vertical or horizontal positioning is available (x, y or z axis).
Displacement	- 1.5 inch D.A. maximum.
Force Limit	- 1,500 lb. peak (3.5 g-peak with human).
Payload	- 250 lbs. maximum.

COMBINED NOISE AND VIBRATION FACILITY



C-5 ELECTRODYNAMIC VIBRATION SYSTEM

The C-5 system is a small electrodynamic vibration system designed for experimental vibration protocols with human or animal subjects. The exciter can be operated in one of three configurations.

1. Air bag supported tractor seat.
2. Spring supported aircraft seat.
3. Spring supported primate seat with load cell interface.

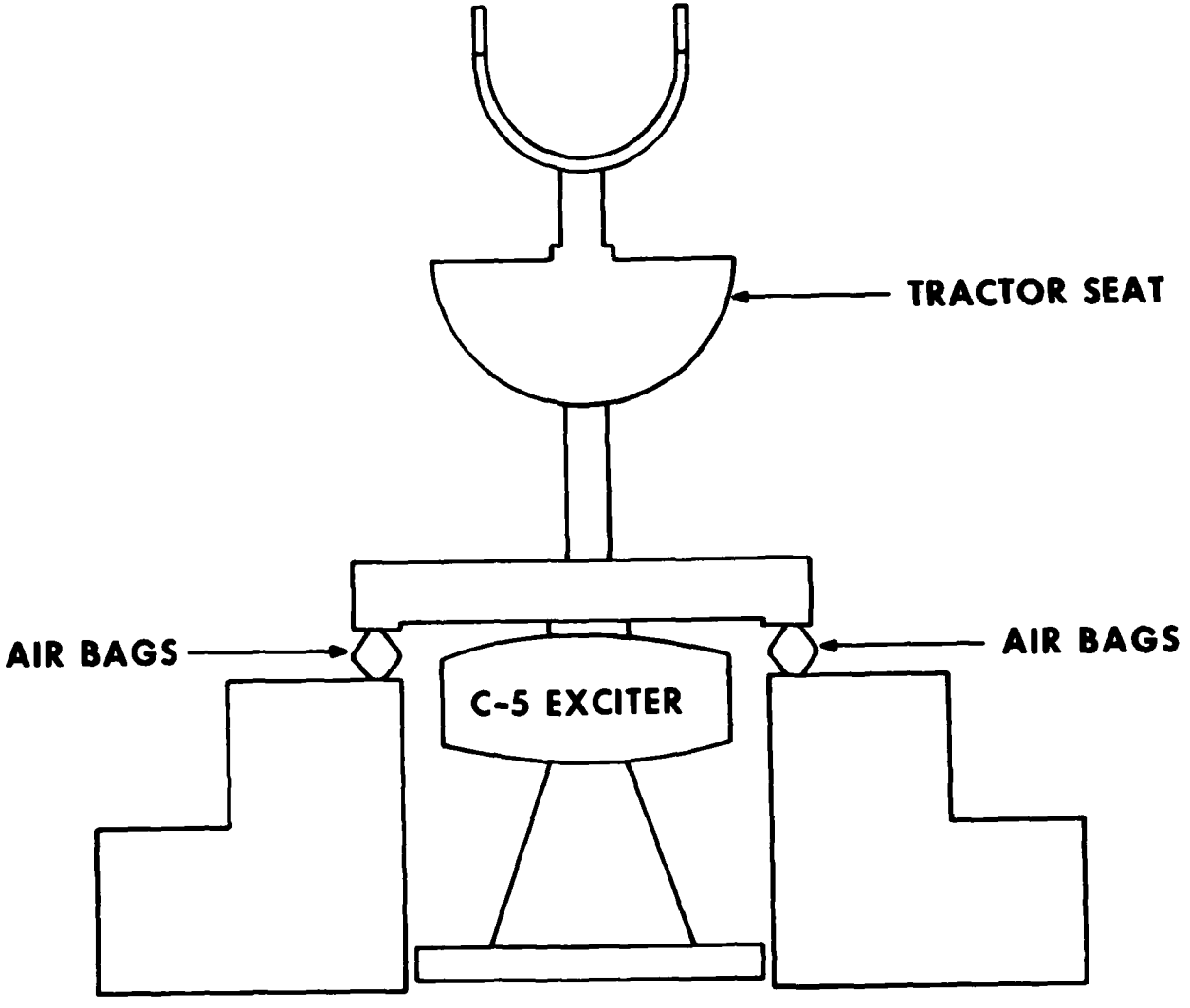
The forcing function to the power amplifier is controlled by an automatic shutdown system. This system, upon command, ramps the signal up to full power or down to zero power in normal operation; and also will bring the system to a gradual stop if any preset limit is exceeded.

The C-5 system can be patched to a DEC PDP-11/34 Data Collection and Analysis system to provide for data analysis and/or closed-loop operation. Software and hardware currently exists for on-line closed-loop control of its frequency and amplitude.

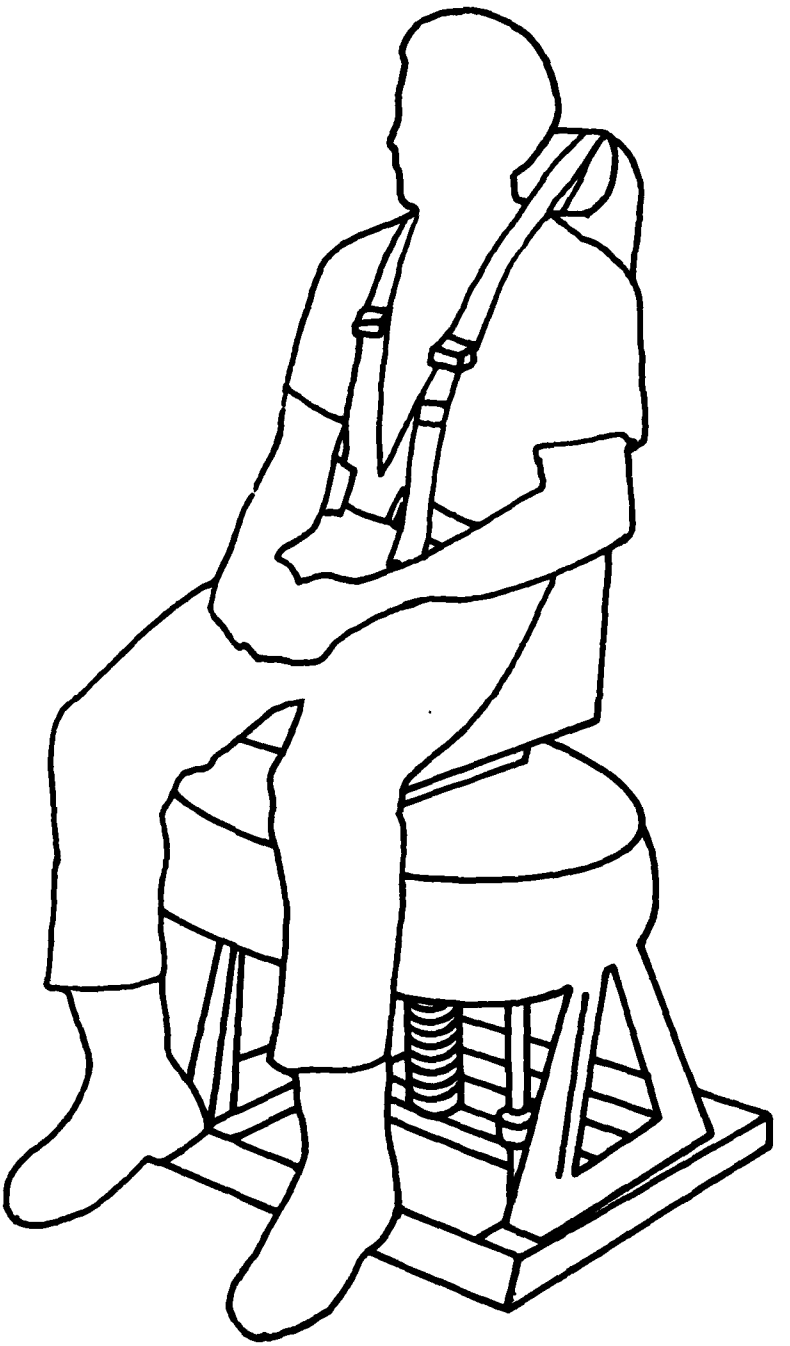
C-5 Electrodynamic Vibration System Specifications

Frequency	- 5 HZ to 500 Hz.
Motion	- Sinusoidal or random, z axis only.
Displacement	- 1.0 inch D.A.
Force Limit	- 650 lbs. maximum (3 g-peak with 200 lb. payload).
Payload	- 200 lbs. maximum with spring or air suspension.

C-5 AIR BAG SUPPORTED TRACTOR SEAT



C-5 SPRING SUPPORTED SEAT



DEC PDP-11/34 DATA ACQUISITION AND PROCESSING SYSTEM

BASIC HARDWARE:

1) 11T34 CPU with 32 K words of MOS Memory.
2) 400 + Hard-Wired Instructions.
3) M9301-YB Bootstrap and Console Diagnostic.
4) DL11-WA Line Frequency Clock and Serial Line Interface.
5) LA36-CE, 300 BAUD (30 CPS) Decwriter II.
6) RK11J 1.25 million word Disk Drive and Controller with removable disk.
7) RK05F 2.5 million word disk drive with nonremovable disk.
8) ADK11-KT Real Time Analog Data Acquisition Package consisting of:
    a) 12 Bit, 16 Channel Single Ended or 8-Channel Differential A/D Converter Package with 40 KHz max single channel acquisition rate (25 μsec/ channel).
    b) Dual Programmable Clock.
    c) Distribution Panel.
    d) UDRI MODIFICATION
        16-Channel synchronous sampling and filter modules with four independently selectable bandwidths of 2 Hz, 10 Hz, 20 Hz or 100 Hz per channel with channel decoder and driver boards.
9) DR11-KT 16 Bit Digital I/O Port.
10) 8-Channels of D/A (2-AA11-K modules).
11) DL11-C asynchronous serial-line interface set-up for 9600 BAUD for graphics terminal.
12) Tektronix Model 4010-1 Graphics CRT Terminal including:
    a) Option 36- Data Communication Interface plus Minibus Extender.
    b) Option 16 - DEC PDP-11 to DL11-C Interface.

13) Tektronix Model 4631 Hard Copy Unit.

14) Acoustic Coupler with maximum thru rate of 300 BAUD.

BASIC DEC Supplied SOFTWARE:

1) RT11 Operating System.
2) FORTRAN IV with real time-extensions.
3) LABAPP-11 Applications Package.
4) DEC Diagnostic Routines.

UDRI DEVELOPED SOFTWARE:

1) Interactive routine to set filters for A/D package.
2) Routine to adapt UDRI modification to DEC A/D package.
3) Routine to supply phase-related forcing functions for SIXMODE and related tracking tasks.
4) Routines to process data from SIXMODE such as PSD, etc.
5) Routine to drive Tektronix 602 CRT monitor.
6) Routine to use either the DECWRITER or the Tektronix Graphics Terminal as the master communication terminal.
7) Routines to acquire, process, and analyze data related to compressive loading of vertebral specimens.
8) Routine to transfer data to the WPAFB CDC 6600 computer by use of an acoustic coupler.
9) Routines to acquire and process data for computation of driving point impedance and transmissibility.
10) Various plotting routines for graphic display of experimental data.
11) Routine for display of experimental data in a histogram format.
12) Various listing routines for sorting and obtaining hard copy and of experimental data.
13) Routines to digitize analog data stored on FM magnetic tape and transfer to disk storage.

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